Ecology of Slimy Sculpin

(*Cottus cognatus*)

in the Chena River, Alaska

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ECOLOGY OF SLIMY SCULPIN

(*COTTUS COGNATUS*)

IN THE CHENA RIVER, ALASKA

A

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ABSTRACT

The purpose of this study was to gather information on the ecology of slimy sculpin (Cottus cognatus) in the upper Chena River. Three major topics were examined: age and growth, food habits, and habitat preferences.

Age of fish was analyzed by length frequency and otoliths. Chena River sculpin were slow growing, reaching a maximum length of 86 mm in 7 years. Stomach contents were examined to determine contribution of different prey to the diet. Chironomids and large mayflies were most important in the diet; electivity indices indicated positive selection for them. Habitat preferences were examined by capturing fish, and measuring habitat variables at the point of capture. These data were analyzed using multiple regressions on principal components. No significant correlation was found between number of sculpin caught and habitat variables of depth, velocity, and substrate type.

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INTRODUCTION

Though not often seen, slimy sculpin (Cottus cognatus Richardson) may be the most abundant fish in clear Alaskan streams. It is the only member of the genus Cottus that is found in interior Alaska (Morrow 1980). Since sculpin of several species are often found in areas that are also occupied by trout, they have frequently been cited as potential competitors with trout (Schallock 1966, Brockson, et al. 1968, Craig and Wells 1976). They have also been considered as possible prey for larger fish (Scott and Crossman 1973), or as predators on fish eggs and fry (Hunter 1959, Patten 1971, Clary 1972). In many streams sculpin have been shown to contribute a large proportion of the total fish production (Chapman 1965, Goodnight and Bjornn 1971, Mann 1971, Petrosky and Waters 1975). Because of their abundance and their potential role in trophic dynamics of streams, any attempt to describe an interior Alaskan stream ecosystem would be incomplete without the inclusion of slimy sculpin.

The purpose of my study was to gather information on the ecology of slimy sculpin in the upper Chena River system. I had three major study objectives: age and growth, food habits, and habitat preferences.

Accurate descriptions of fish habitat are difficult to achieve. However. the Cooperative Instream Flow Service Group in Fort Collins. Colorado. has developed methods for quantifying fish distribution and for analyzing the effects of changes in flow on fish (Bovee and Cochnauer 1977). Instream flow analysis has become an important management tool. but its weaknesses are often overlooked. I hoped. therefore. as part of my project to both use and critically analyze some of their methods.

SITE DESCRIPTION

General description

The origin of the Chena River is in a mountainous region approximately 144 km east of Fairbanks. From there it flows 240 km to its junction with the Tanana River southwest of Fairbanks. There are three major branches of the upper Chena: the North Fork, the East (or Middle) Fork, and the South Fork (Figure 1).

The Chena River is a clear water, rapid run off stream with no glacial input. Maximum discharge usually occurs during April and May as a result of melt off and spring rains. Water temperatures remain at 0 degrees C from October until May, and reach a maximum of around 13 degrees C in the upper Chena during July (Howe 1981). Numerous ground water springs limit the extent of winter ice cover.

Fish species, other than slimy sculpin, found in the upper Chena are arctic grayling (Thymallus arcticus), round whitefish (Prosopium cylindraceum), and chinook salmon (Oncorhynchus tshawytscha).

A more complete description of the Chena River has been written by Frey (1969).

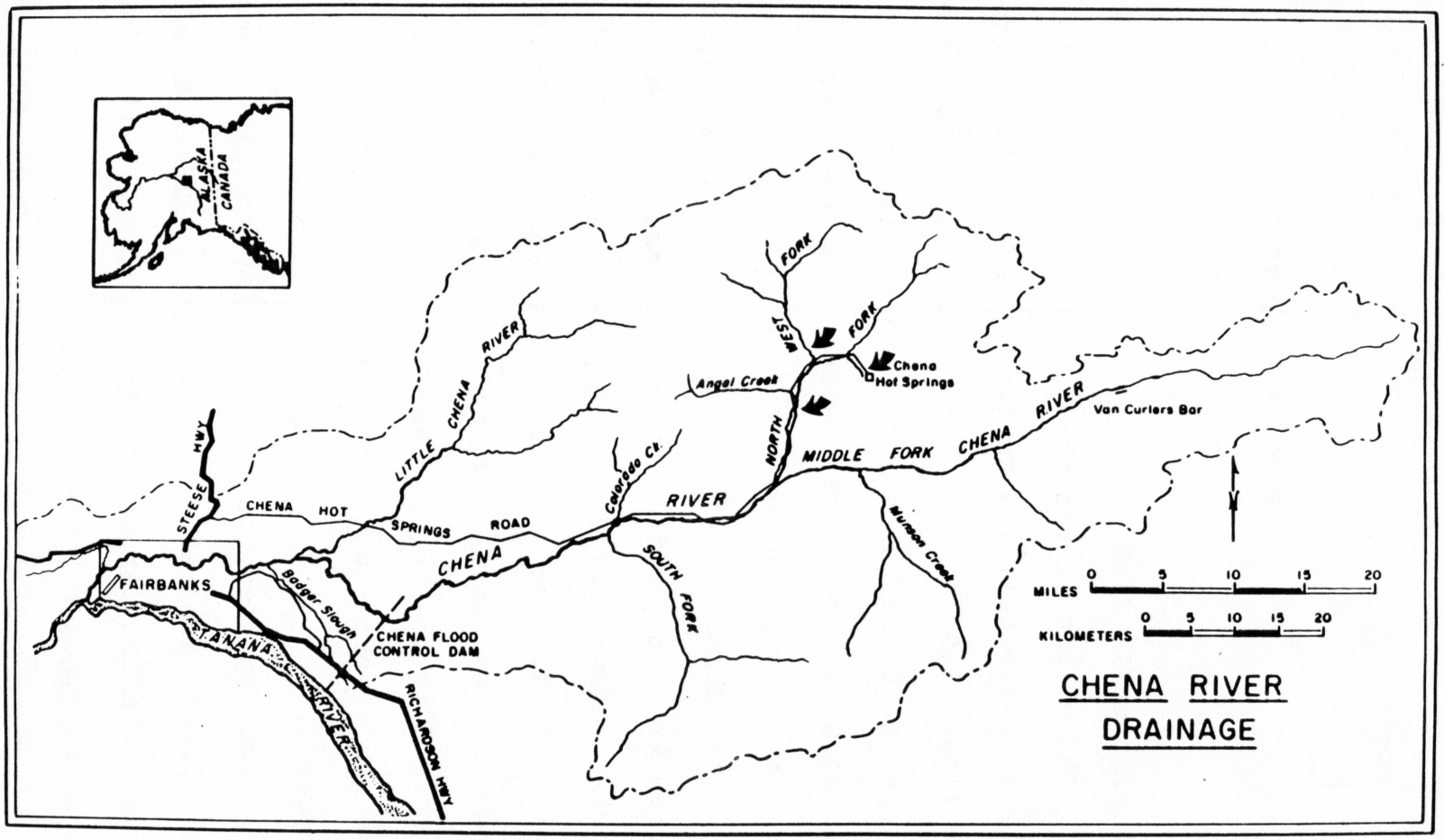

Figure 1. The Chena River watershed. Sampling sites are indicated by arrows.

Site Selection

Study sites chosen were easily accessible, and contained a large range of habitat variability. I chose one area in Monument Creek, one in the West Fork, and one in the North Fork of the Chena River. Though a few grayling were occasionally seen at all three sites, neither they nor round whitefish were abundant. No grayling or round whitefish spawning activity was apparent at any of the sites.

Monument Creek is a second-order stream which drains into the North Fork. The site averaged 6 m wide. with a maximum width of 11 m. and was 21 m long. It contained one pool (approximately 1.5 m deep) with a mud and sand substrate. and another shallow pool near the bank on the outside edge of a bend. The remainder of the site ranged from 0.1 to 0.5 m in depth. with a gravel and rubble substrate (-3 to -8 on the phi scale; Cummins 1962).

The West Fork is a fourth-order stream which drains into the North Fork downstream of the Monument Creek-North Fork junction. This site was 21 m long, varied in width from 18 to 22 m. and contained mainly a long section of smooth water which developed into a riffle midway through the site. A pool with a sand bottom ran along one bank. The substrate was mainly large cobble (-6 to -8 on the phi scale). Maximum depth in the riffle was 0.75 m. and in the pool 1.5 m.

On the North Fork, my study site was a small side channel separated from the main stream by a low gravel bar. The site was 11 m long, and 5 to 8 m wide. It contained a long pool, 1.0 m deep, bordered by a shallow (0.3 m) run. The substrate in the pool was loose sand. The run contained mainly small cobble and large pebble (-4 to -5 on the phi scale).

METHODS

Age and Growth

Most fish for age and growth analysis were collected during July 1979 in the main channel of the North Fork adjacent to my site.

Total lengths of 341 fish were measured to develop a length frequency plot for aging. These fish were preserved in formalin. and measured within five days. Lengths given are preserved total length. however conversion factors from preserved to fresh length can be found in Bailey (1952).

A total of 58 fish from all 3 sites were collected on July 18 and August 14 of 1979 for aging. These fish were preserved in 70% ETOH. Otoliths were removed by making a longitudinal cut through the center of the head. They were examined immediately. then stored either dry in small envelopes or in a glycerin and alcohol solution.

Otoliths were examined under a dissecting microscope. Aging was done following Bailey (1952). Opaque zones represent summer growth; translucent bands indicate winter growth. The center of each otolith consists of an opaque core which is surrounded by a translucent band. Outside this core is the opaque band which represents the first

summer's growth (Bailey 1952).

Food Habits

Fish for the food habits analysis were taken from both Monument Creek and the West Fork in August through October of 1979, and at the West Fork in June and July of 1980. Three samples were taken in August of 1979, and one sample in each of the other months. Twenty fish were taken from each site sampled on each date. These fish were collected by kicking the substrate in the area in front of a 2.4 x 0.9 m seine with 3.2 mm bar mesh. The fish were preserved immediately in 70% ETOH. Observation of the first several fish indicated that they did not regurgitate their stomach contents when preserved by this method. Fish were taken to the laboratory and their stomachs removed at a later date. As the fish were small (18 to 75 mm), and generally gaped their mouths upon preservation, I did not feel that continued breakdown of the contents would be a serious problem after preservation.

In the laboratory, stomachs were removed by making one cut at the end of the esophagus, and another just anterior to the pyloric caecae. Contents were removed, and identified under a dissecting microscope. Of the undigested contents, mayflies (Ephemeroptera) and stoneflies

(Plecoptera) were identifed to genera, all other organisms to family or order. Mayflies and stoneflies which were less than 2 mm in length were identified only to order since key characteristics are not developed at that size.

Only those mayflies and stoneflies which had both a head and at least part of the body were counted. I used this method to avoid overestimating those taxa which could be readily identified through recognition of the head alone. Since chironomids (Diptera: Chironomidae) are soft bodied, the majority of the body was digested rapidly. Therefore, chironomids were counted even if only their head capsule was present. This may have led to overestimation of the relative number of chironomids eaten, but I felt that the error was less than what would have resulted from not counting the head capsules.

The contribution of each prey item to the sculpin diet was estimated by both numbers and volume. The volume contribution was determined by the points method of Hynes (1950). In this method, the contribution of each prey type is estimated by eye as a percent of the total stomach contents. I first rated the fullness of each stomach, with maximum fullness given a value of twenty, and empty stomachs given a zero. Prey types in each stomach were then also given a number rating, with their sum equaling the total rating given that stomach. A reference set of stomachs ranging from one to twenty in fullness was kept

for comparison to reduce bias in rating. All stomachs from a sampling period were examined at once.

Periodicity of feeding was also qualitatively examined by comparing the fullness ratings given to stomachs taken from samples of sculpins caught at 3 hour intervals over a 24 hour period on July 18-19,1979. Twenty fish were collected every 3 hours for this comparison.

The number and volume contribution of each prey type was determined as a percent of the total identifiable numbers and total identifiable volume. This was done separately for 4 size classes of sculpin (15-29, 30-44, 45-59, and ≥60 mm), and for fish of all sizes. Contributions of prey types are expressed as percent of identified contents, rather than as percent of total contents. This was done to allow clearer comparisons of prey types.

Benthic invertebrate samples taken with a D-net at an adjacent upstream site by Howe (1981) were used to evaluate abundance in the environment for electivity indices. Numbers of mayflies and stoneflies over 2 mm in length were determined by Howe (1981) for his own study. I determined numbers of all other organisms. Once again, mayflies and stoneflies over 2 mm in length were identified to genera; all others were identified to family or order. Water mites were listed under the non-taxonomic but convenient heading, Hydracarina.

Abundance of each prey type in the environment was

compared to its abundance in stomachs by Ivlev's electivity index (Ivlev 1961), and through a linear index developed by Strauss (1979). The linear index is simply the difference between the two porportions ($r_i - p_i$), where r_i is the percent of a prey type in the stomachs, and p_i is the percent of that prey type in the environment. For Ivlev's index this difference is then divided by the sum of the prey type's proportions in the stomach and environment $(r_i - p_i / r_i + p_i)$. Approximate confidence limits for Ivlev's index were calculated following the method suggested by Strauss (1979).

Both Ivlev's index and the linear index range from -1.0 to +1.0. Positive values indicate that the proportion of the food item in the diet is greater than in the environment (positive selection). Negative values indicate that the food may be inaccessible, or that it is avoided by the fish (negative selection). Values near zero indicate random selection of prey from the environment.

Habitat Preference

Distribution data were collected by a method similar to one suggested by Bovee and Cochnauer (1977). I used an individual capture technique in which points to be sampled were randomly selected from an imaginary grid across each sample site. A 2.4 m long by 1.6 m wide seine with 3.2 mm

mesh was used which enclosed an approximately 1 m^2 area of stream. Within this area sculpins were disturbed by kicking in the substrate, and were washed by the current into the net. Captured sculpins were then measured to the nearest millimeter (total length). To prevent recapture, they were kept in a bucket of water until sampling at that site was completed.

Measurements of depth, current velocity, and substrate type were taken at each point sampled regardless of whether a sculpin was collected. Velocity measurements were taken with a Pygmy-Gurly current meter (Teledyne-Gurly Corp., Troy, NY). Since sculpin are benthic, and would be most affected by velocities at the substrate level, the cups of the meter were positioned as close as possible to the substrate. Three velocity readings were taken at different points within each sample area. The minimum, maximum, and average current readings were used in later analyses. Depth and substrate type were also recorded at three points within the area sampled. Substrate type was measured on the phi scale (Cummins 1962). Accurate substrate size identification was facilitated by the use of a plexiglass sheet in which standard size holes based on the phi scale were cut. These standard holes were compared to the size of the substrate particles. Depth was measured to the nearest centimeter. The minimum, maximum, and average values for both depth and

substrate were also used in analyses.

When collecting distribution data, it is assumed that the fish have free movement between different habitat types. If the fish are trapped in an area due to low water, for instance, it would be incorrect to say that is their preferred habitat, since they actually have no opportunity to choose. None of my samples was taken in areas which did not have an outlet, or in which the fish could have been trapped. All my samples were taken between 10:00 am and 3:30 pm.

I compared number of fish captured per sample at each site using one way analysis of variance (ANOVA). I also compared length of fish at each site, and velocity at each site. BMDP79 2V (Dixon and Brown 1979) was used for these calculations.

Distribution data were also analyzed using multiple regressions on principal components. Independent variables used in environmental analysis are often correlated. Green (1979) points out that when this occurs, the evaluation of significance and rank order of importance of individual independent variables is meaningless. Principal component analysis creates a set of uncorrelated independent variables (principal components) which are linear functions of the original variables. In my study, the length of each fish captured was used as the dependent variable in one case, and in another case, the number of

fish captured was the dependent variable. Independent variables were principal components derived from the three values recorded (maximum, minimum, and average) for depth, substrate type, and current velocity. These calculations were done using BMDP79 4R (Dixon and Brown 1979).

The number of fish captured per sample at different velocity, substrate type, and depth ranges was also compared. This was done separately for 4 size groups (15-29, 30-44, 45-59, and ≥60 mm). Levene's test (Dixon and Brown 1979) showed that variances for all velocity values were not equal, so numbers were first transformed using $\log_e (X + 1)$. After transformation, variances remained unequal. Consequently, the Brown-Forsythe test and the Welch test for equality of means were used, since they do not require equal variances. Levene's test, the Welch test, and the Brown-Forsythe test were all calculated using BMDP79 P7D (Dixon and Brown 1979).

Production

An estimate of sculpin production in the Chena River was made for comparison with other studies. Instantaneous rate of mortality was calculated using the 58 sculpins collected July 18, and August 14, 1979, which had been aged via otoliths. The natural log of number of each age was regressed against age. The slope of that line was the instantaneous mortality rate. A length - weight relation-

ship was calculated using 53 sculpins which had been collected July 18-19, 1979. The fish were preserved in formalin, and their lengths and wet weights measured over two months later. This length - weight relationship was used to estimate mean weights at capture for the fish aged via otoliths. These weights were then used to calculate production by the Allen graph method (Chapman 1978). Beginning with an arbitrary number of 100 age I fish, and using the mortality rate I calculated, numbers at each year up to age VI were calculated. Total number of fish from age I to VI was 254. These numbers were plotted against mean weight at each year. The area under the curve was estimated by using

$$(n_1+n_2)((w_2-w_1)/2)$$

where: n=numbers and w=mean weight. This area is an estimate of annual production of 254 sculpins, ages I to VI, assuming a steady state population with constant mortality and growth rates and recruitment of 100 age I fish. A minimum estimate of production during age 0 was obtained using the biomass of 100 fish at age I. Production after age VI was assumed to be insignificant. The production estimate was then expanded to an area of 1.0 ha, using data on population density from 1.0 m^2 samples taken during studies of habitat preference.

RESULTS

Age and Growth

Ages determined from peaks of the length frequency diagram are largely in agreement with those determined by examination of otoliths (Figure 2). The mesh of the net used to collect sculpin for the length frequency analysis was large enough to allow most of the age-I fish to escape; so they are represented by only a small peak. Age-I fish appear as a peak at about 25 mm; the large center peak of the length frequency represents both age-II and age-III fish; age-IV fish appear as a small peak at about 62 mm. Beyond age IV, the lengths of different cohorts overlap extensively. making any age classification difficult from the length frequency. Examination of otoliths showed that age-I sculpin had a mean length of 28.8 mm. age-II 44.5 mm. and age-III 54.2 mm (Table 1). Few fish over age III were identified by otoliths. Because of small sample size (n=3), sizes given for age-IV (x=65.3mm) and age-V (x=80.0mm) fish must be considered rough estimates. Two fish over age V were identified, each 86 mm long; one was age VI, and one age VII.

Young of the year were first found in the last week of July in 1979. These fish were all 7 mm long, and had

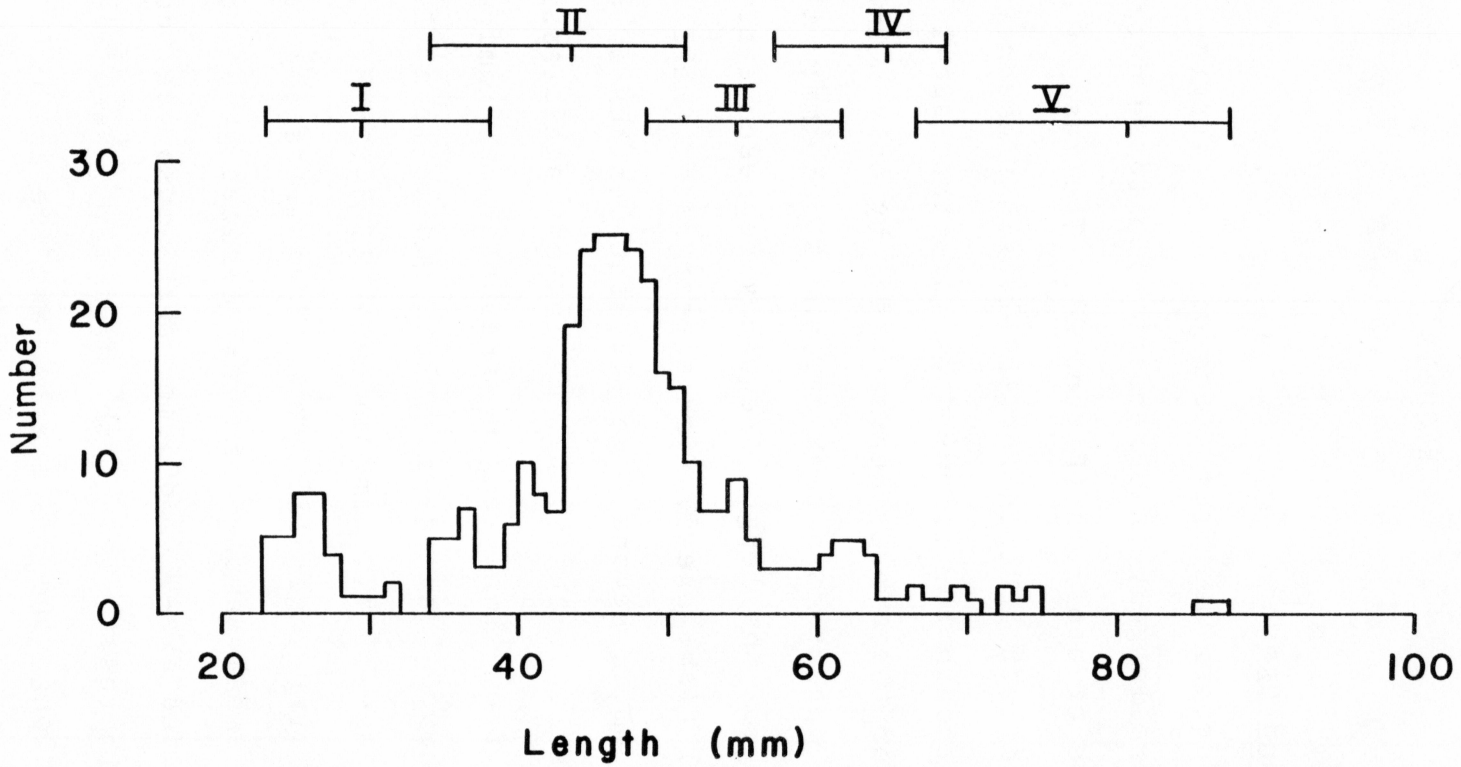

Figure 2. Length frequency of 341 slimy sculpin collected from the North Fork of the Chena River on July 18 and 19, 1979. Bars above the histogram represent ages determined from otoliths. Length of the bar indicates the range, center mark indicates the mean.

Table 1. Sample size (n), mean length, and standard deviation (S.D.) of lengths determined by otoliths for slimy sculpin from the Chena River, Alaska (this study), Chandalar River, Alaska (Craig and Wells 1976), and Valley Creek, Minnesota (Petrosky and Waters 1975).

Age	CHENA RIVER			CHANDALAR RIVER			VALLEY CREEK
	n	mean length (mm)	S.D.	n	mean length (mm)	S.D.	mean length (mm)
1	18	28.8	4.0	32	36.6	4.4	65
2	20	44.5	4.4	12	50.8	4.6	81
3	12	54.2	4.1	22	65.0	9.3	95
4	3	65.3	11.9	33	74.1	7.5	111
5	3	80.0	11.4	29	85.6	5.8	---
6	1	86.0	----	6	94.8	7.9	---
7	1	86.0	----	3	101.3	2.5	---

completely absorbed their yolk sacs. Fry less than 15 mm long continued to be found until sampling was completed in late August.

Slimy sculpin in the Chena River were smaller at any age than those in two other studies; one in the arctic, and one in Minnesota (Table 1). Minnesota sculpin collected in August were approximately twice as large at each age as those from the Chena River (Petrosky and Waters 1975). Sculpin from the Chandalar River, which originates in the Brooks Range, were also consistantly larger than the Chena River sculpin (Craig and Wells 1976).

Food Habits

In terms of numbers, chironomids (Diptera: Chironomidae) made the greatest contribution to sculpin stomach contents (Figure 3). However, mayflies (Ephemeroptera) made the greatest contribution by volume (Figure 3). Chiromomids are small compared to mayflies, and it requires a large number to make a significant contribution to the sculpin diet.

Only one sculpin stomach contained fish. Eight newly hatched sculpin fry were found in the stomach of a 79 mm sculpin taken from the West Fork.

Unidentified contents accounted for approximately 45% of the total contents by volume. These consisted mainly of sclerotized body parts from different insects.

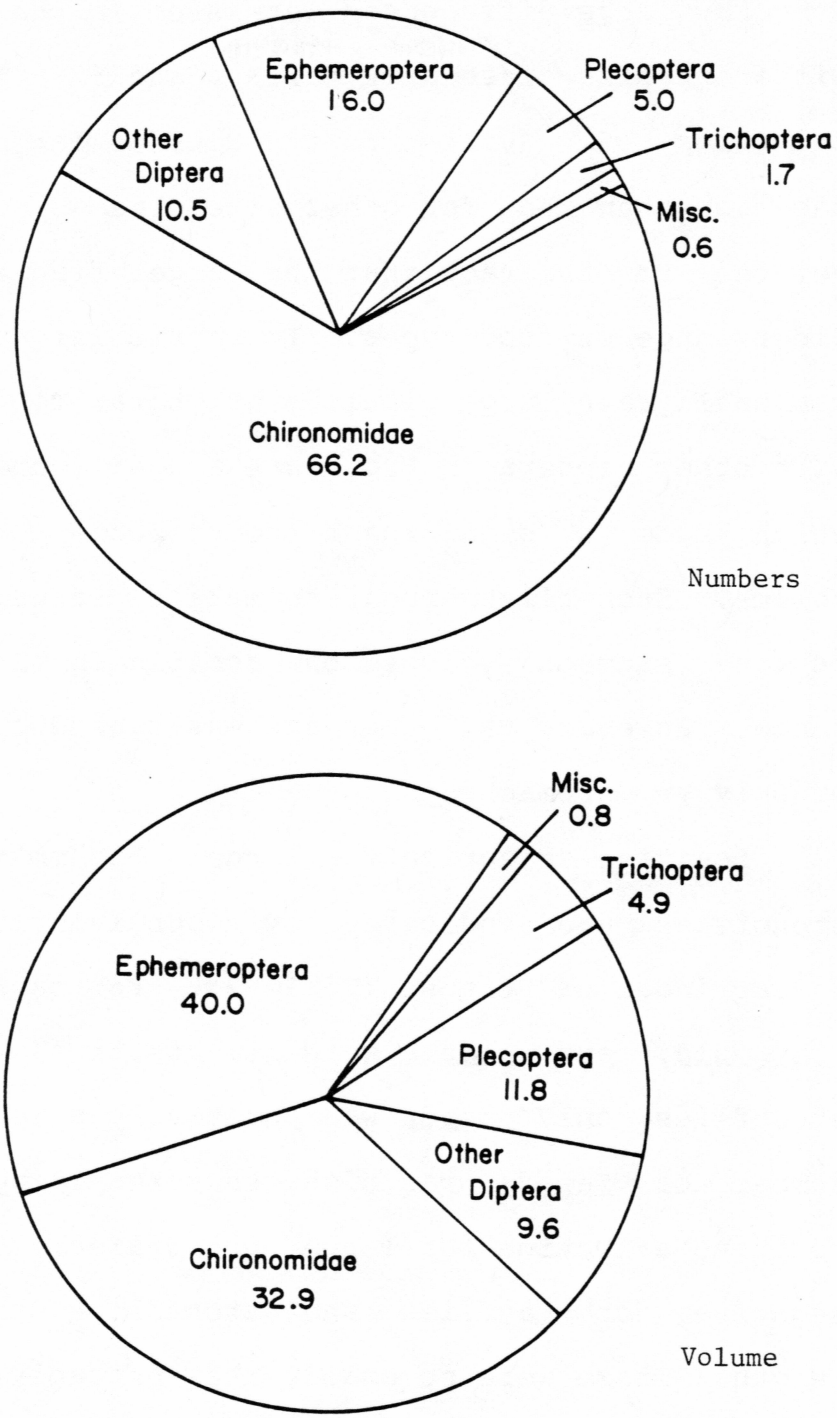

Figure 3. Contribution of major prey types to sculpin stomach contents by percent of identifiable numbers, and percent of identifiable volume.

Few large differences were seen in the food habits of different size classes (Figures 4 and 5). The volume contribution of mayflies to the diet of large (≥60 mm) fish was less than that for other size classes. This probably relates to the fact that the larger fish also consumed a wider range of food types. In particular, these fish occasionally ate large tipulids (Diptera: Tipulidae) (listed with other Diptera in Figures 4 and 5), and Trichoptera, which made a significant contribution to the stomach volume. Stoneflies appear to make a larger contribution to the stomach volume of sculpin in the 30-44 mm size range. However, this increase was caused by the contents of only two stomachs.

Positive selection for large (>2 mm) mayflies and stoneflies was indicated by both Ivlev's index and the linear index of Strauss (Table 2). For mayflies, Epeorus, Cinygmula, and Baetis were all positively selected. For stoneflies, only Zapada was positively selected, but the number of Zapada was high, thus resulting in an overall positive selection for large stoneflies. Selection was negative for mayflies and stoneflies under two mm in length. These were so small, they probably escaped notice by the sculpin, and may have also easily been overlooked during examination of stomach contents. Numbers of small mayflies and stoneflies in the benthic samples were high, and caused the total mayfly and stonefly selection values

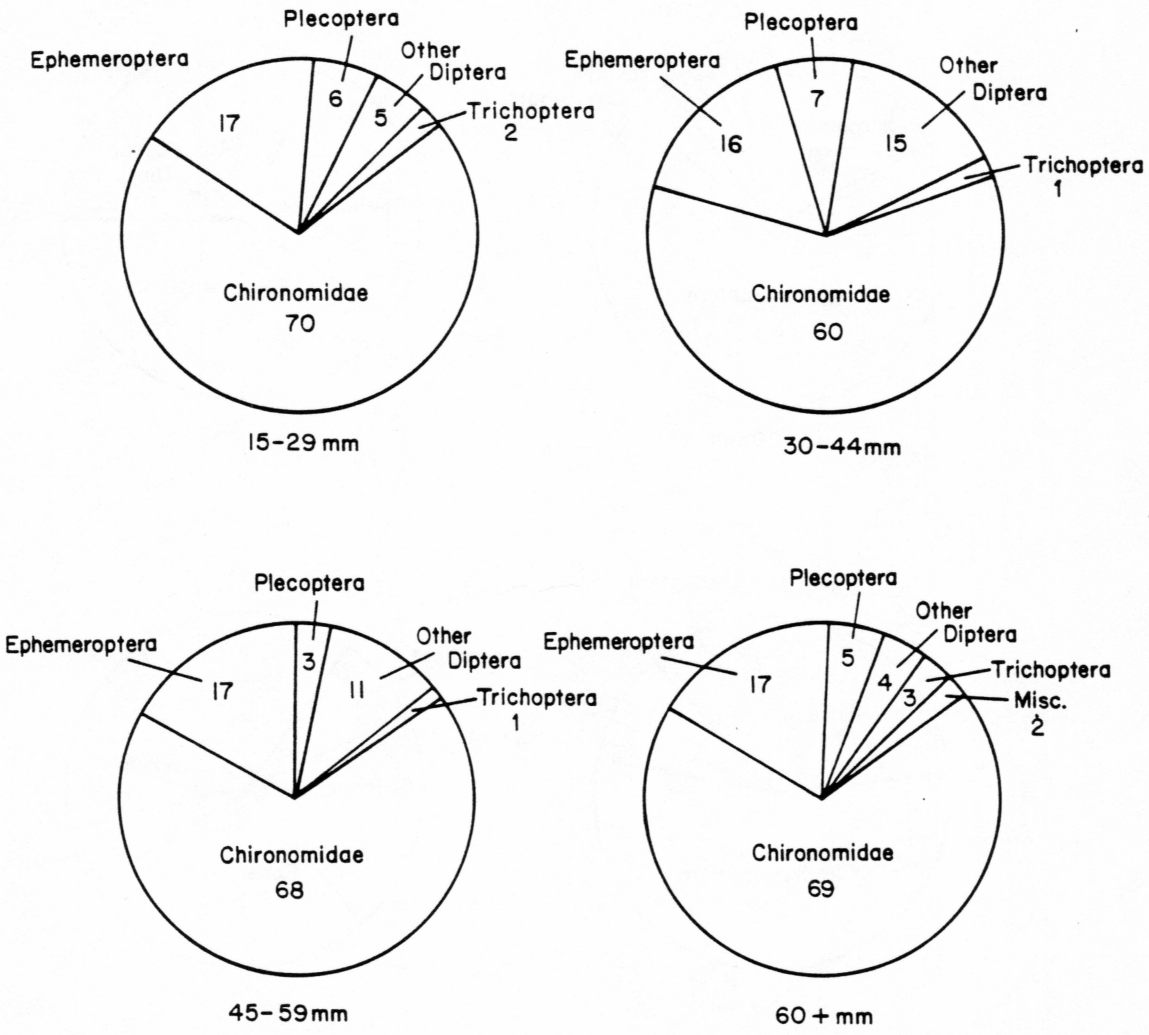

Figure 4. Contribution of major prey types to stomach contents of four size classes of sculpin (percent of identifiable numbers).

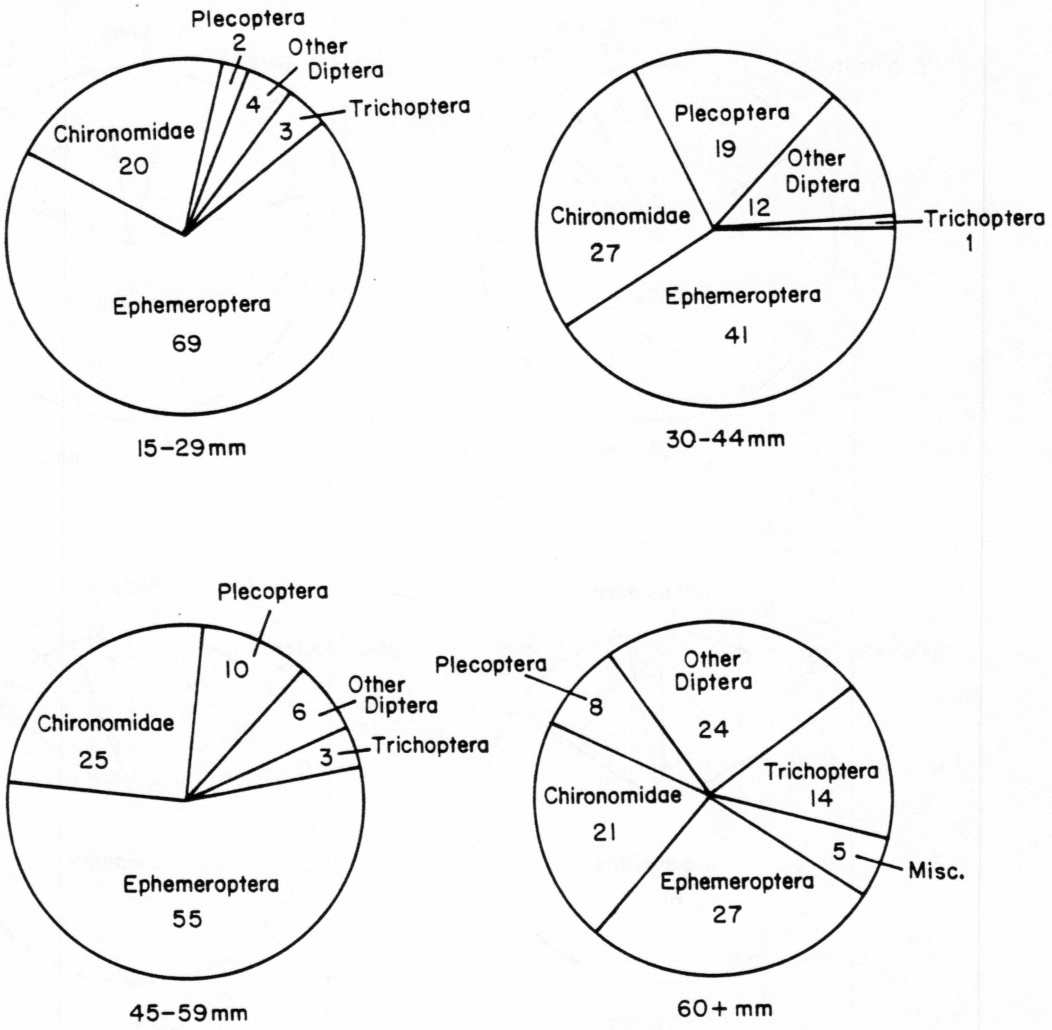

Figure 5. Contribution of major prey types to stomach contents of four size classes of sculpin (percent of identifiable volume).

Table 2. Electivity values calculated from Ivlev's index and a linear index developed by Strauss (1979), with 95% confidence intervals. The percent of prey type in stomach is r_i, p_i is the percent of prey type in environment.

Prey Type	r_i	p_i	Index Value	
			Ivlev	Strauss
Total Ephemeroptera	16.00	28.14	-0.275 ±0.030	-0.121 ±0.018
Small Ephemeroptera[b]	0.61	20.03	-0.941 ±0.001	-0.194 ±0.006
Large Ephemeroptera[a]	15.38	8.12	0.309 ±0.098	0.073 ±0.019
Epeorus	3.51	0.78	0.637 ±0.341	0.027 ±0.009
Cinygmula	5.97	3.89	0.211 ±0.141	0.021 ±0.012
Baetis	4.55	1.95	0.400 ±0.219	0.026 ±0.010
Ameletus	0.06	0.08	-0.111 ±0.784	-0.000 ±0.000
Siphlonurus	0.00	0.02	-1.000 ±0.000	-0.000 ±0.001
Ephemerella	4.44	5.55	-0.157 ±0.201	-0.003 ±0.004
Total Plecoptera	4.98	6.37	-0.122 ±0.082	-0.023 ±0.011
Small Plecoptera[b]	0.92	3.25	-0.559 ±0.049	-0.023 ±0.005
Large Plecoptera[a]	4.06	3.12	0.131 ±0.152	0.009 ±0.010
Zapada	1.78	0.83	0.368 ±0.338	0.010 ±0.006
Alloperla	1.85	1.94	-0.023 ±0.169	-0.001 ±0.007
Paraperla	0.00	0.01	-1.000 ±0.000	-0.000 ±0.000
Utaperla	0.00	0.01	-1.000 ±0.000	-0.000 ±0.000
Isoperla	0.25	0.06	0.629 ±1.290	0.002 ±0.002
Capniidae	0.00	0.27	-1.000 ±0.000	-0.002 ±0.001
Total Diptera	76.74	49.35	0.217 ±0.022	0.274 ±0.021
Chironomidae	66.22	39.83	0.249 ±0.029	0.026 ±0.240
Other Diptera[c]	10.52	9.52	0.050 ±0.078	0.010 ±0.015
Ceratopogonidae	0.12	0.16	-0.146 ±0.512	-0.000 ±0.002
Dolicopodidae	0.00	0.90	-1.000 ±0.000	-0.000 ±0.000
Dueterophlebiidae	0.00	0.003	-1.000 ±0.000	-0.000 ±0.000
Psychodidae	0.00	0.08	-1.000 ±0.000	-0.001 ±0.000

Table 2 (concluded)

Prey Type	r_i	p_i	Index value	
			Ivlev	Strauss
Simuliidae	7.75	5.84	0.140 ±0.104	0.019 ±0.013
Tipulidae	0.80	0.65	0.100 ±0.000	0.000 ±0.000
Total Trichoptera	1.67	1.28	0.131 ±0.238	0.004 ±0.006
Brachycentridae	0.06	0.06	0.026 ±1.043	0.000 ±0.001
Glossostomatidae	0.06	0.14	-0.388 ±0.372	-0.001 ±0.001
Limnephilidae	0.43	0.89	-0.350 ±0.156	-0.005 ±0.003
Rhyachophilidae	0.00	0.20	-1.000 ±0.000	-0.002 ±0.001
Coleoptera	0.00	0.01	-1.000 ±0.000	-0.000 ±0.000
Collembola	0.00	0.01	-1.000 ±0.000	-0.001 ±0.000
Hemiptera	0.00	0.01	-1.000 ±0.000	-0.000 ±0.000
Hydracarina	0.00	3.02	-1.000 ±0.000	-0.030 ±0.002
Terrestrial insects	0.00	0.01	-1.000 ±0.000	-0.000 ±0.000
Copepoda	0.00	0.01	-1.000 ±0.000	-0.002 ±0.000
Nematoda	0.00	0.04	-1.000 ±0.000	-0.000 ±0.000
Oligochaeta	0.12	11.46	-0.979 ±0.001	-0.113 ±0.004

a organisms greater than 2 mm in length
b organisms less than 2mm in length
c all Dipterans except Chironomids

to be negative.

Positive selection was shown for chiromomids. Slight positive selection was also shown for other dipterans, but the confidence limits for both indices fell below zero in this case.

Few Trichoptera were found in either the stomach contents or the benthic samples. Slight positive selection was indicated by both indices, but in both cases the lower confidence limit fell below zero. The number of Trichoptera was too small to give any definite indication of sculpin preferences.

Although large numbers of oligochaetes were found in benthic samples, almost none was found in the stomachs. Ivlev's index, and the linear index were negative for oligochaetes. Hydracarina were also common in benthic samples but absent from the stomachs.

In all cases where the percent of prey type in the stomach (r_i) was 0, Ivlev's index was -1.00, while the value of Strauss's linear index varied in these cases depending upon the percent in the environment (p_i).

About two percent of all sculpin examined were parasitized by Schistocephalus solidus, a cestode which is a procercoid in copepods and a plerocercoid in the body cavity of fish (Hoffman, 1967).

Little variation was seen in the mean fullness ratings given to stomachs taken from sculpin collected at

regular intervals over a 24 hour period (Figure 6). The stomachs remained slightly over half full (a rating of 10 to 14) throughout the sampling period.

Habitat Preference

Analysis of variance showed significant differences between numbers of fish per sample captured at each site ($P<0.05$). Newman-Keuls multiple comparison tests (Zar 1974) showed that numbers at the North Fork were greater than those at Monument Creek and the West Fork. There were also significant differences ($P<0.05$) in length of fish caught at each site. Fish caught at the West Fork were larger than those at Monument Creek and the North Fork. There was no significant difference ($P>0.05$) between water velocities at the three sites. The relationship of all these values is illustrated in Table 3.

Multiple regressions of both individual length and number captured per sample against principal components derived from the habitat variables showed no strong relationship at any of the sites individually or at all sites combined (Table 4). When length of fish was regressed against habitat variables at each site, the maximum R^2 found was 0.56 for the North fork; 56 percent of the variability in lengths had been accounted for by variation in habitat variables. The R^2 values for the

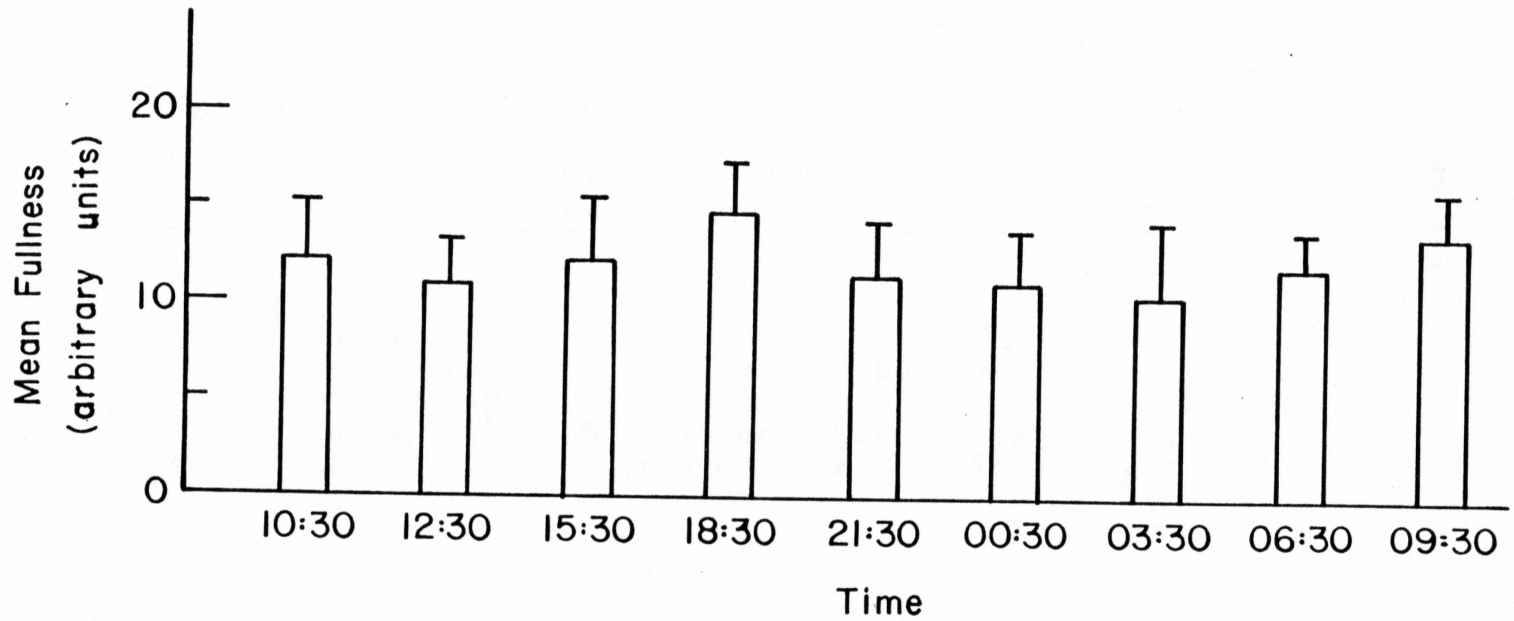

Figure 6. Fullness of stomachs from sculpin collected at intervals over a 24 hour period July 18-19, 1979. Bars represent one half of 95% confidence intervals. Fullness is judged on a relative scale of zero (empty) to 20 (maximum fullness).

Table 3. Means ($\bar{x}$) and standard deviations (S.D.) for number of sculpin captured per sample, sculpin length, and water velocity at sample sites on the North and West Forks of the Chena River, and Monument Creek.

Site	Number per Sample		Individual Length (mm)		Velocity (cm/sec)	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
North Fork	2.2	3.6	32.9	16.4	44.3	18.3
West Fork	0.9	1.2	46.9	15.6	45.1	18.4
Monument Crk.	0.5	0.9	37.7	13.8	42.6	27.8

Table 4. Multiple correlation coefficients (R^2) calculated from regression on principal components. Numbers of sculpin per sample, and length of each sculpin are regressed against minimum, maximum, and average values of velocity, depth, and substrate type. probability (P) of rejecting H_o: there is no relation between the variables, and degrees of freedom (df) for testing are also shown.

Site	Length			Number		
	R^2	P	df	R^2	P	df
West Fork	0.34	<0.10	9,48	0.32	<0.10	9,50
Monument Creek	0.33	>0.10	9,29	0.22	>0.10	9,60
North Fork	0.56	<0.10	9,139	0.23	>0.10	9,57

West Fork and Monument Creek were 0.34 and 0.33 respectively.

Regressions of number of sculpin caught per sample against the habitat variables gave a maximum R^2 of 0.32 (West Fork). The values for the North Fork and Monument Creek were 0.23 and 0.22 (Table 4).

When data from all three sites were combined, the R^2 for length were 0.23, and for numbers was 0.10. The habitat variables examined did not account for a large amount of the variability in sculpin distribution.

When average number per sample was plotted against incremental values of velocity, depth, and substrate type, a tendency for the 15-29 mm fish to peak in numbers near the low values of each parameter seems to appear (Figures 7, 8, and 9). The highest number of 15-29 mm fish per sample was found at a velocity of 21-40 cm/s. Numbers per sample for this size class also peaked at a depth of 10-20 cm, and at a substrate size of -5 phi. However, the Brown-Forsythe and Welch tests show that there is no signigicant difference ($P>0.05$) in mean number caught at each parameter value. Since few samples were taken at any substrate sizes less than -4, those substrate sizes are not shown on Figure 8. Confidence intervals calculated for each average are generally very wide (Figures 7, 8, and 9).

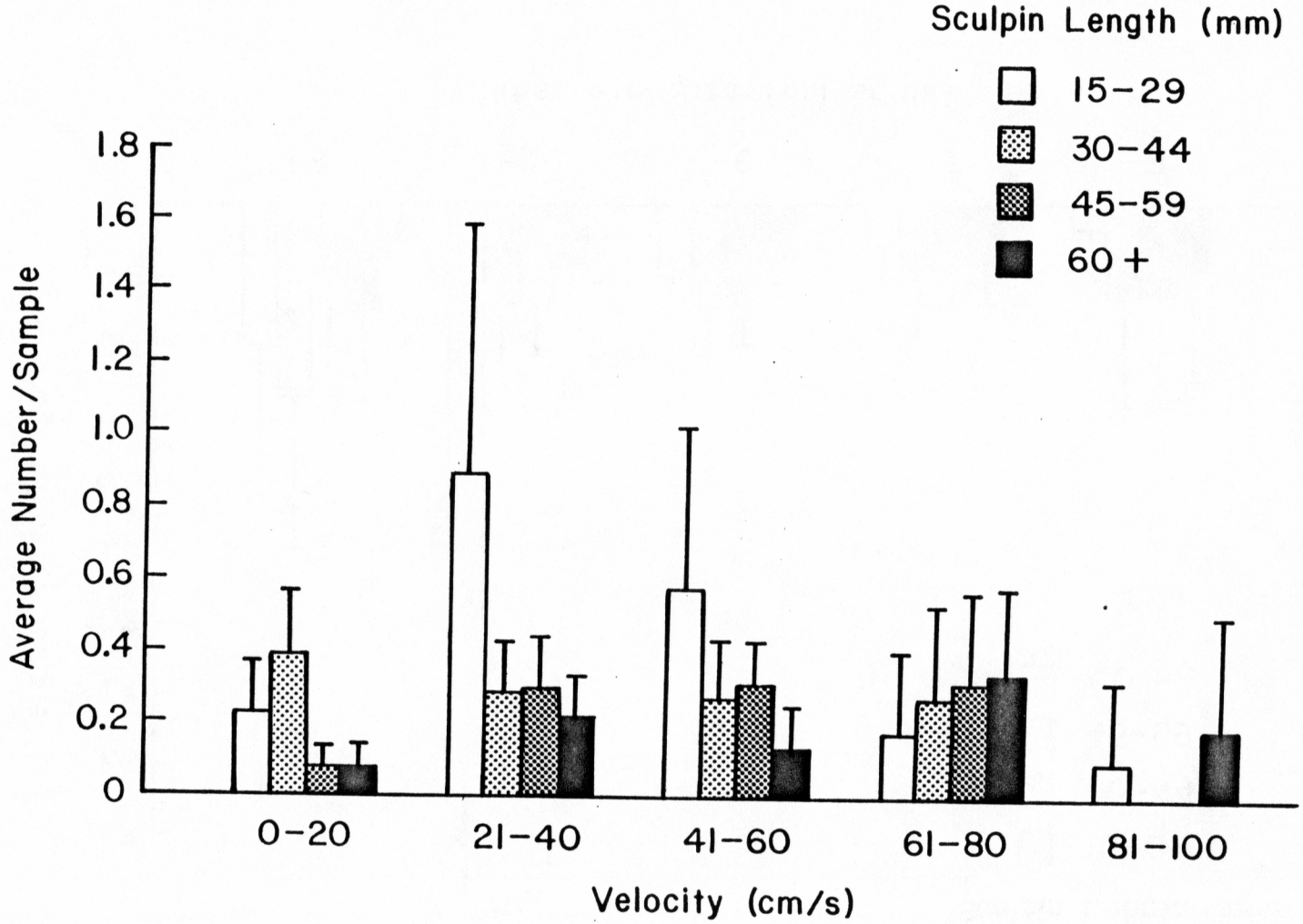

Figure 7. Distribution of four size classes of slimy sculpin with respect to water velocity. Bars represent one half of 95% confidence intervals.

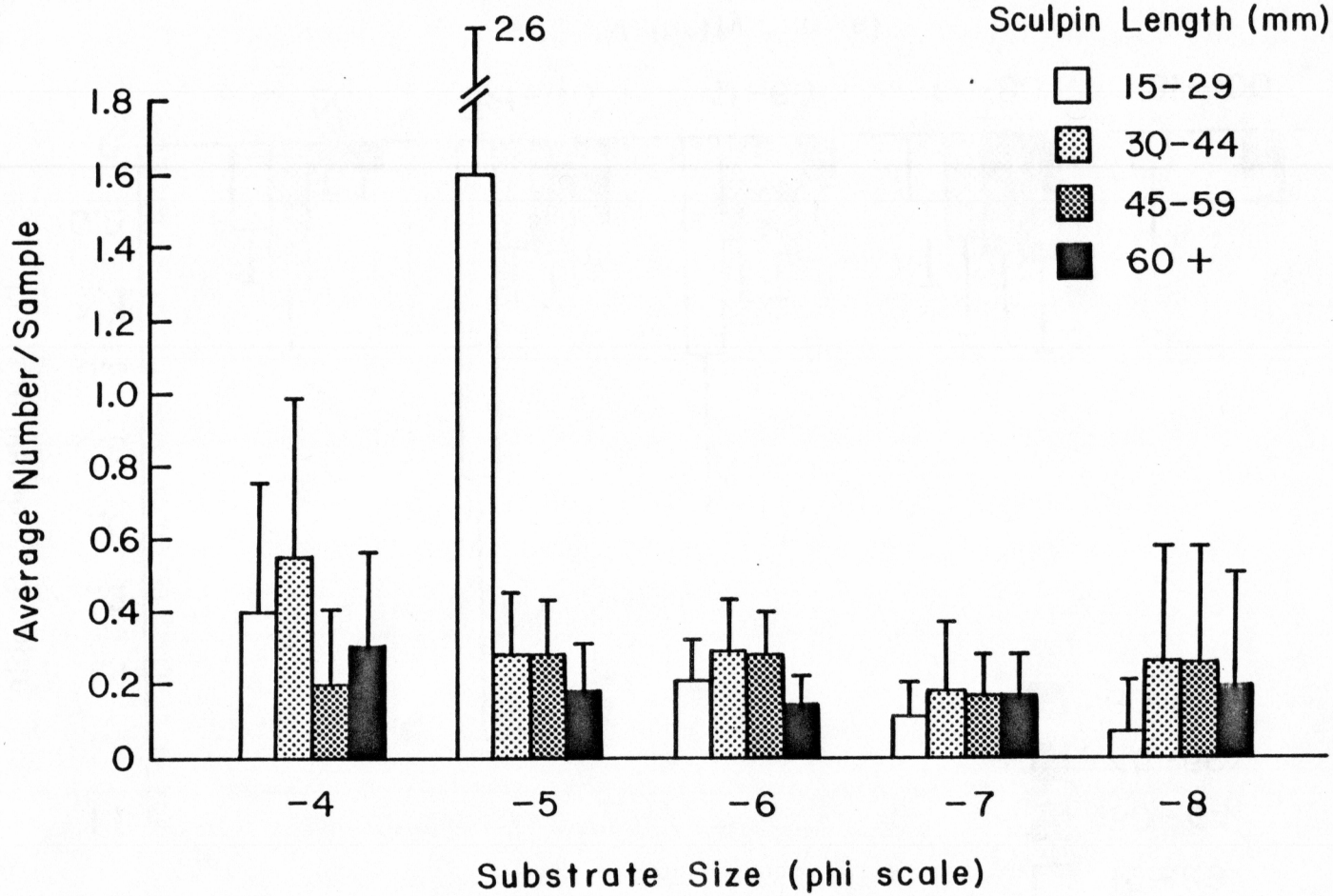

Figure 8. Distribution of four size classes of slimy sculpin with respect to substrate type as measured on the phi scale. Bars represent one half of 95% confidence intervals.

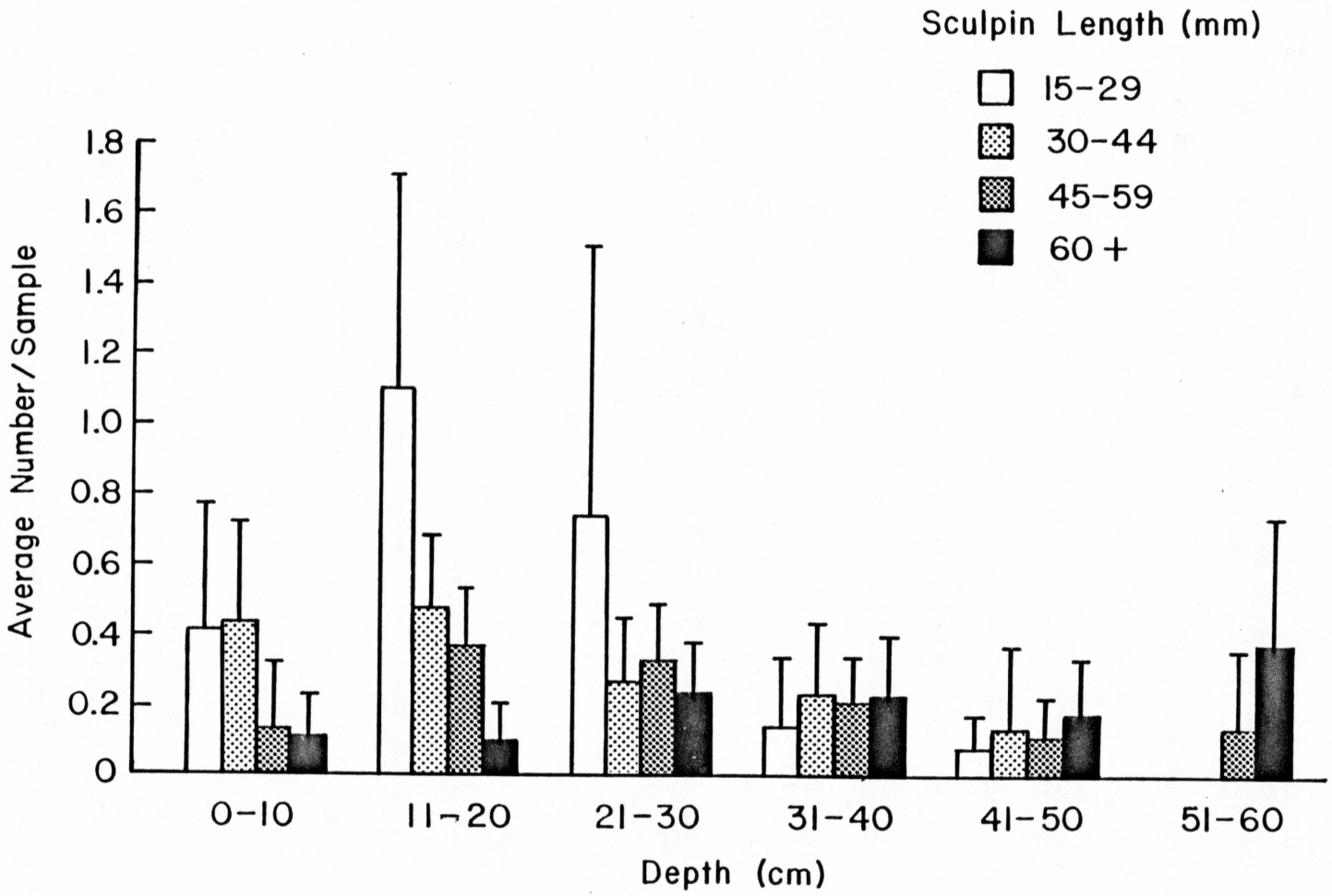

Figure 9. Distribution of four size classes of slimy sculpin with respect to water depth. Bars indicate one half of 95% confidence intervals.

Sample distribution

During the study of habitat preference at the three study sites, 247 sculpins were captured from 207 seine samples, each covering a 1.0 m^2 area. The mean density was 1.2, or about one sculpin per 1.0 m^2.

The numbers captured in the 207 samples were not normally distributed (Figure 10). In the majority of samples, no sculpin were captured, while in a few cases, more than ten sculpins were found in the net. Therefore, a large number of samples must be taken to obtain a reasonable estimate of sculpin density. Furthermore, normal distribution statistics should not be applied to such data.

Production

The instantaneous rate of mortality calculated from 55 fish aged via otoliths, was 0.48, or an annual mortality of 38%. The length - weight relation calculated from 53 fish (r=0.97) was:

$$\log_{10} W = (3.13) \log_{10} L - 5.22$$

where W=weight (g), and L=length (mm). Annual production, using this length - weight relation and my estimate of mortality rate, was 8.5 kg/ha. The estimate of mean poplation biomass was 13.6 kg/ha. This is based on the assumption that sculpin density is approximately

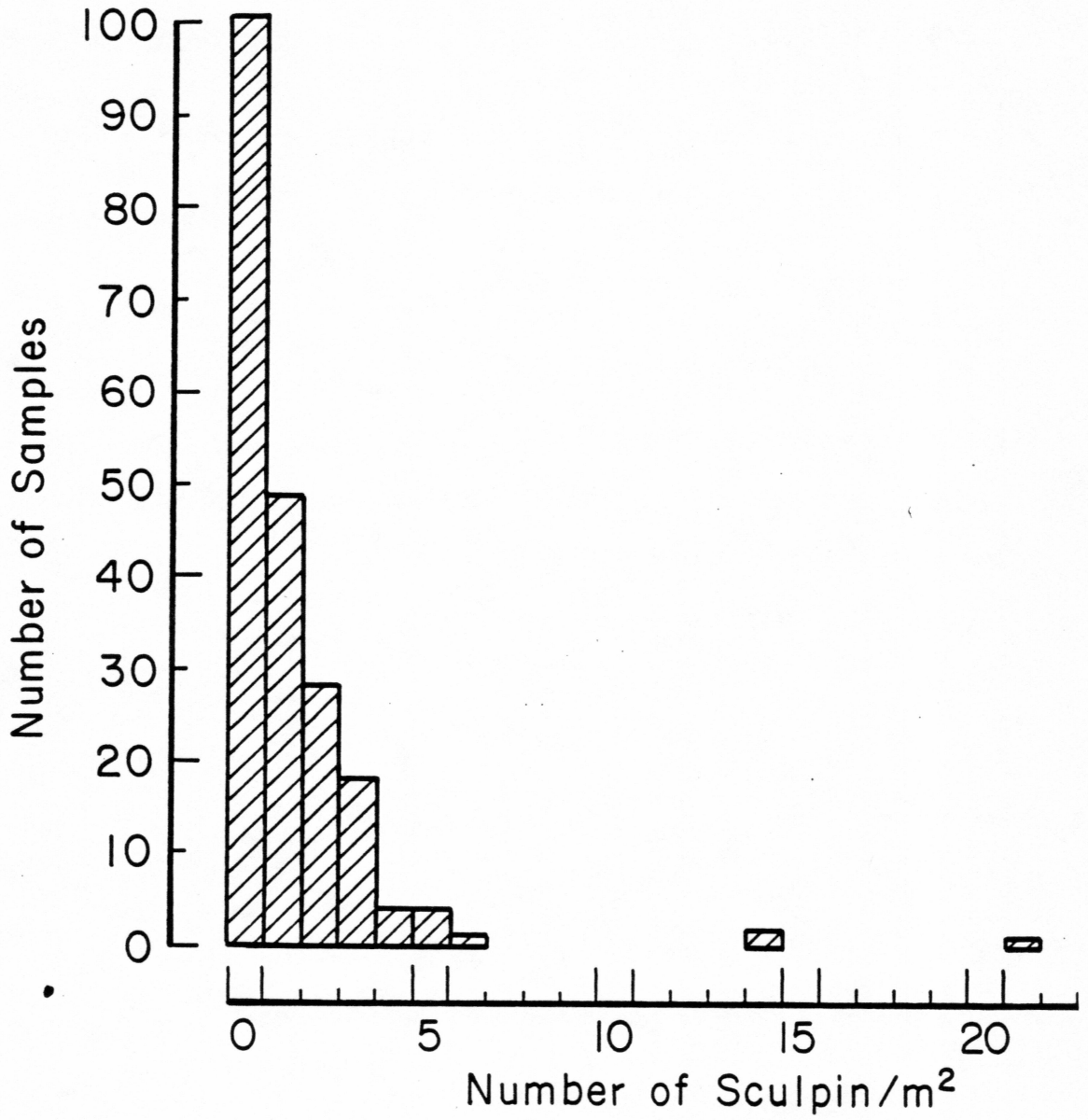

Figure 10. Histogram showing the distribution of sample values found when collecting slimy sculpin in 1.0 m^2 areas of a stream.

10,000/ha. The ratio of annual production to mean biomass (P/B) was 0.62.

DISCUSSION

Age and Growth

Chena River sculpin take almost five years to attain the length reached in two years by those in Minnesota (Figure 11). However, they live longer than those in Minnesota. The oldest fish found in Minnesota was only five years old; the oldest I found in the Chena River was seven years old. These are common phenomena in northern fish populations, and may be associated with the harsh conditions, short summers, and comparatively low productivity of northern streams (Hobbie 1973).

Large numbers of sculpins under 20 mm in length were found at my sites (especially the North Fork) in early June of 1980. Since age 0 fish were not found until late July of 1979, I assume that those fish less than 20 mm found in early June 1980 must be age I, as the age 0 fish for 1980 probably had not yet emerged. With this in mind, the 36.6 mm mean size for age I fish observed by Craig and Wells (1976) seems quite large. Craig and Wells did not state in what month their sculpin were collected. Their larger mean sizes for each age could be caused by collections made later in the year than mine. It is also possible that the two rivers differ in some way which causes the disparity in size.

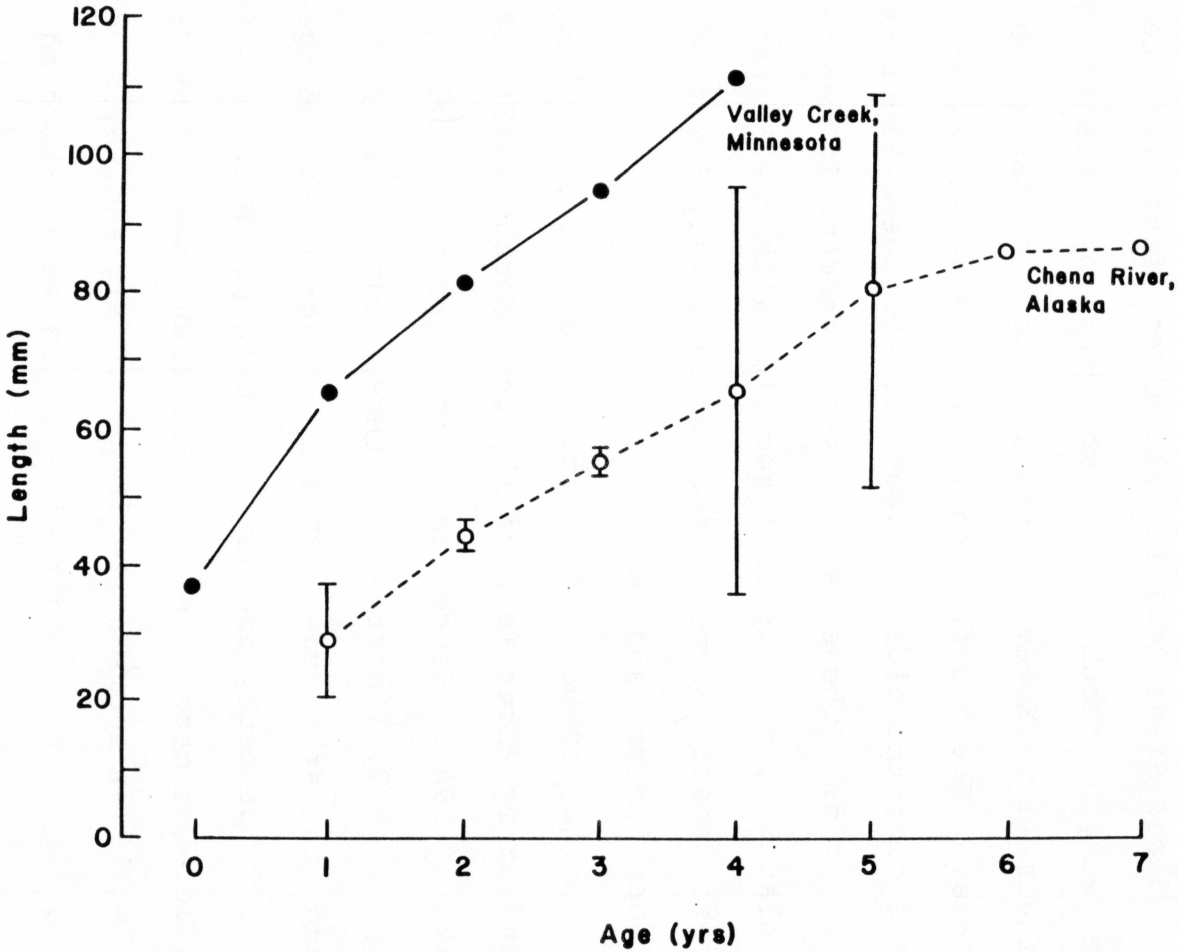

Figure 11. Growth rates of slimy sculpin from the Chena River, Alaska (this study), and from Valley Creek, Minnesota (Petrosky and Waters 1977). Bars on Chena points indicate 95% confidence intervals.

Food Habits

I found Strauss's linear index (1979) to be preferable to Ivlev's for interpretation of food habits data. Ivlev's index $((r_i - p_i)/(r_i + p_i))$ has been the most widely used and accepted food selection index for many years. Strauss (1979) points out, however, that values calculated from the index are not normally distributed. Atchley, et al. (1976) have shown that values calculated from a ratio of continuous variables are leptokurtotic and skewed to the right. Two problems arise from this: the expected value of the index when random feeding occurs may not be zero, and the variance calculated from several replicate samples is not a good measure of the deviation of the calculated index value from its expected value (Strauss 1979).

The odds ratio $(r_i (1-p_i)/p_i (1-r_i))$ developed by Fleiss (1973) and Jacobs (1974), is often used in electivity studies. It too, however, is a ratio of continuous variables and would presumably suffer the same problems as Ivlev's. Berkson (1958) raises further objections to the odds ratio. He feels that when comparing two values, only the differnce between the two is important. In the study of the effects of smoking on health, for instance, only the increased number of deaths among smokers is important. By taking ratios, he feels this essential difference is obscured. Both Berkson and Strauss choose the same index

as appropriate. This index is simply $(r_i - p_i)$.

I felt that a significant advantage of the linear index appeared when comparing organisms which were of varying abundance in the environment, but never appeared in the sculpin stomachs. When the percent of any prey type in the stomach (r_i) is 0, Ivlev's index reduces to simply $-p_i/p_i$, or -1. The confidence interval for Ivlev's index resulting from Strauss's formula (Strauss 1979) will always be ± 0.00 in this case. Strong negative selection is indicated by these results, but often this is misleading. For example, Hydracarina which were fairly abundant, were rated equally with Dueterophlebiidae (Diptera) of which I found only one. When r_i is 0.00, and p_i is large, negative selection probably is taking place, but when p_i is very close to zero (as with Paraperla in Table 2) it is more likely that there is little or no selection. The r_i sample size is probably too small to reveal any of the rare prey type in the stomach. The linear index gave values very close to zero for organisms which were rare in the environment and did not appear at all in the stomachs. Common organisms that did not appear in the stomachs were given larger negative values.

The results of the electivity studies indicate that slimy sculpin are not generalists. They show preferences for large mayflies and chironomids. Any alterations in the stream environment which would result in a change in

the abundance of these organisms might also affect the sculpin population. An increase in another predator which also relies on mayflies and chironomids could lead to competition between sculpin and that predator, since the electivity values indicate that the sculpin may not readily shift to another prey.

Schallock (1966) suggests that sculpin and arctic grayling may compete for food. A comparison of published food habits data for interior Alaska grayling, and my own sculpin data (Table 5) shows that some diet overlap does occur. Though sculpin are bottom feeders and grayling usually feed in the water column, the sculpin may crop the bottom fauna sufficiently to affect the amount of drift available to the grayling. Wojcik (1955) states that grayling are bottom feeders. Generally, this is not believed to be true. Morrow (1980), however, does say that grayling feed on the bottom in fall when terrestrial insects are not available. At this time interaction between the two species would be increased. If food is limiting at any time, some competition would be possible.

Moyle (1977), in his examination of sculpin-salmonid interactions, states that, even when diet overlap occurs, several other conditions must be satisfied before competition can result. Moyle lists three conditions: food types must be equally available to each species; food must be a potentially limiting factor; and this limiting food

Table 5. Frequency of occurrence of major prey types in sculpin stomachs and in grayling stomachs collected in interior Alaska. Grayling data from Wojcik (1955), Vascotto (1969), Schallock (1966), Tripp and McCart (1974), and deBruyn and McCart (1974).[a]

	Grayling					Sculpin
	Wojcik (Interior Alaska)	Vascotto (McManus Creek)	Schallock (Faith Creek)	Tripp & McCart (Donnelly River)	deBruyn & McCart (Firth Creek)	Chena River
Chironomidae	46	55	18	12	29	71
Ephemeroptera	21	29	85	1	9	46
Plecoptera	6	23	8	2	19	21
Trichoptera	49	22	15	15	7	7

[a]Schallock's data obtained by averaging frequency of occurrence values calculated for July 6, July 20, August 20, and September 6 (Figure 8, Schallock 1966). Wojcik's data obtained by averaging frequency of occurrence values calculated for May 16, June 8, June 15, July 5, August 9, and August 18 (Table 6, Wojcik 1955). Wojcik lists all dipterans together, and notes that the value is primarily chironomids. I used that value for chironomids, and it is, therefore, an inflated estimate.

resource must be in short supply. No studies to this date indicate that these conditions exist in the grayling-sculpin habitat. I have not found any grayling food habits reports in which feeding selectivities have been analyzed. However. if grayling are generalists, feeding randomly on available prey. then they may be more able to shift to other prey types to avoid competition. Food may well not be a limiting factor in the streams. Chapman (1966) and Moyle (1977) point out that, for most salmonids, competition for space is more likely to limit the population than competition for food. Obrebski and Sibert (1976) suggest that, in some cases, fish may actually benefit from other species feeding in the same areas. They speculated that the feeding habits of sticklebacks could make more prey available to co-occuring chum salmon. In the Chena River system, the increase in substrate disturbance caused by feeding of the sculpin may make more invertebrates available in the drift for arctic grayling.

Diet overlap demonstrates the potential for competition, but it is not a strong indication that competition occurs. More concrete evidence for competition could be collected by examining grayling food habits in an area before and after removal of sculpin. If the grayling food habits changed after removal of sculpin, it could indicate that sculpin had been influencing grayling feeding.

The continuous light levels of a northern latitude

summer may contribute to the constant level of feeding activity I found for slimy sculpin in the Chena River. Li and Moyle (1976), however, found the same feeding pattern in Pit sculpin (Cottus pitensis) in California. This feeding pattern may further reduce any competition between sculpin and fish which exhibit diurnal peaks in feeding activity.

Several authors (Pritchard 1936, Hunter 1959, Clary 1972, Scott and Crossman 1973, Morrow 1980) have examined the relationship between the size of various species of sculpin and the intensity of their predation on hatching salmon eggs and fry. Morrow (1980) states that sculpin small enough to burrow into the redd are too small to consume the eggs. Moyle (1977) suggests that, though sculpin do consume large numbers of salmonid eggs and fry, under normal circumstances their effect on the salmonid population is insignificant. Scott and Crossman (1973) state that sculpin are not serious predators on eggs and fry, but several other authors (Pritchard 1936, Hunter 1959, and Clary 1972) have found evidence that large (over 70 mm) sculpin can be quite effective predators. Both Clary (1972) and Hunter (1959) found that sculpin under 50 mm did not consume salmon eggs, and that an average of less than one egg per sculpin was found in fish under 70 mm in length.

Since the majority of my fish were under 70 mm

(Figure 2) it seems that they would not be serious predators on salmon eggs in interior Alaska. Grayling eggs, however, are smaller than salmon eggs. The diameter of fresh grayling eggs is 2.1 mm (Tack 1974). Egg diameter in the 5 salmon species ranges from 4.5 mm to 7 mm (Scott and Crossman 1973). The Chena River sculpin may be able to eat the smaller grayling eggs, and could conceivably have an impact upon the population in this way. Neither I nor Craig and Wells (1976) found any eggs in sculpin stomachs.

Habitat Preference

The necessary conclusion from my study of habitat preferences is that sculpin are distributed evenly across the whole range of velocity, substrate, and depth values I measured. I do not feel, however, that the velocity values recorded are true representations of the velocities experienced by the sculpin. A great deal of variation in the readings was found even within the 1.0 m^2 area enclosed by my seine. Variation occurred depending upon the relationship of the flow meter to large substrate particles. Current velocites measured behind rocks were slow compared to those taken on top of or in front of rocks. Thus it becomes impossible to determine what velocity benthic fish like sculpin are subjected to within the sampling area. Sculpin may, indeed, have velocity

preferences, but they are on too fine a scale to be recognized by my methods.

The instream flow analysis techniques which I hoped to use involve first creating probability-of-use curves. These curves are made by plotting the number of fish caught at each value of a habitat parameter. The value at which most fish are caught is called the optimum and is given a rating of one. All other values are given a percent rating based on the number of fish caught at that value compared to the number caught at the optimum value. These percents are plotted against habitat values to give the probability-of-use curve. The curve can be interpreted as the probability of finding a fish at each value of a habitat parameter. A different curve can be created for each habitat variable. In the methodology of the Cooperative Instream Flow Group (Bovee and Cochnauer 1977), curves for different habitat variables are multiplied together to give a composite probability-of use curve. For instance, to calculate the probability of finding a fish at a velocity of 20 cm/sec, and a depth of 1 m, one would multiply the value read off the velocity curve at 20 cm/sec by the value read off the depth curve at 1 m.

I had hoped to use my own data to develop a probability-of-use curve for the slimy sculpin which could be used in Alaskan studies. After preliminary investiga-

tion, however, it became evident that it would be meaningless to use my data in this manner. The instream flow methodology assumes that, in some fairly narrow range of habitat values, a marked increase in numbers occurs. The numbers within this range must be significantly different ($P<0.10$) from the other values. My own data did not meet this requirement. No velocity value, for instance, showed a significant increase in the number of sculpin caught there. Following their system, I would be forced to assign my entire range of velocity values a rating of one - indicating that one would be essentially certain of finding a sculpin anywhere within the range of velocity values I examined.

I feel that it would be easier to accurately define velocity preferences of fish which are primarily found in midwater. Velocity readings taken in the water column would be less variable than those at substrate level. Probability of use curves have been developed for some midwater fish in the western states (Bovee and Cochnauer 1977) and in Alaska (Wilson et al. 1980). I think, however, that the problems I encountered while trying to determine microhabitat of sculpin may also apply to midwater fish.

Accurately identifying the point at which a fish may be found is difficult, if not impossible. The act of sampling may disturb the fish, or the collection area may

need to be defined in such a broad way that a great deal of variation may occur within it. Sampling methods vary in their effectiveness from one habitat type to another. It is often necessary to use a different sampling method in pools, for instance. than is used in riffles. Results from different sampling techniques may not be comparable since one method may be more effective than another. Thus peaks in numbers may be due to increased sampling efficiency rather than to habitat preferences of the fish.

Probability of use curves can be created from virtually any set of data as long as a peak in numbers occurs. Though these curves may be useful. I think the danger lies in accepting them as completely accurate descriptions of fish distribution. especially when they refer to benthic fish or other organisms whose habitat varies rapidly within a small area. Errors made in developing a curve for one habitat parameter will be perpetuated when that curve is multiplied together with others to form the composite probability of use.

If the sculpin are. indeed, responding to fine-scale differences in habitat that could not be measured by my methods, they still are widely distributed across the range of habitat types found at my sites.

Finger (1979) studied a stream in Oregon which was occupied by three species of sculpin. He found that the reticulate sculpin (Cottus perplexus) occupied both pools

and riffles when found alone, but when it shared a stream section with torrent sculpins (C. rhotheus) it was primarily found in pools. The Paiute sculpin (C. beldingi) was found in riffles of higher velocity than torrent sculpins. When they occurred together, however, the Paiute sculpin was forced to burrow into the gravel.

Sculpin are the only benthic fish in the upper Chena. In this situation they would presumably be free to exploit the entire range of habitats which they can physically withstand. They are free of interspecific competition and, as their population increases, will spread to occupy their fundamental niche (if food remains abundant). Possibly, if the slimy sculpin was sharing its environment with similar fish, it too would exhibit a narrower distribution.

The slimy sculpin's range does overlap with prickly sculpin (C. asper) and the coastrange sculpin (C. aleuticus) in southeastern coastal areas of Alaska (Morrow 1980), and these species could occasionally be found together in lower reaches of coastal streams. It would be interesting to examine their distribution in these areas to see if they still occupy as wide a variety of habitats as they do in the Chena River.

Production

The production estimate I calculated is based on data

which were not collected for that purpose. It is intended to be no more than a approximation which may be used as a starting point for future studies.

A true value for sculpin production in a subarctic stream may be less than the one I calculated (P=8.5 kg/ha). Sculpin used in the production estimate were collected in mid July, 1979, rather than at the beginning of their growing season. Weights used are thus not true weights at age, but rather an inflated value which includes some months of production since that age was achieved.

Petrosky and Waters (1975) found that slimy sculpin production in a Minnesota stream was 59.4 kg/ha. Though my production value is probably an overestimate, it is still substantially lower than theirs.

The P/B ratio of 0.62 for slimy sculpin in the upper Chena River is relatively low, suggesting that their food base is somewhat limiting. Detrital input in the upper Chena River is quite low, and may limit production by stream invertebrates (C.A. Cowan, University of Alaska, Fairbanks, personal communication). Low invertebrate production may affect production by sculpin, and could contribute to the lower value I found.

CONCLUSIONS

1. Slimy sculpin in the Chena River. Alaska exhibit slower growth than those in Valley Creek, Minnesota. Age-I slimy sculpin from the Chena River average 30 mm in length. The oldest sculpin found was identified by otoliths to be seven years old, and was 86 mm in length.

2. The proportion of mayflies (Ephemeroptera) and chironomids (Diptera: Chironomidae) in slimy sculpin stomachs was significantly higher than in the environment indicating a positive selection for these prey types.

3. Chena River slimy sculpin. due to their small size, are probably not serious predators on salmon eggs or fry.

4. Contribution of major food types to the diet remained fairly constant across all size classes. The larger sculpin (above 60 mm) were able to occasionally ingest large Tipulidae and Trichoptera which made a major contribution to their stomach volume.

5. Examination of stomachs indicated that feeding activity remained constant throughout a 24 hour period in late July.

6. Slimy sculpin exhibited a widespread distribution, and

were present in all habitat types examined. No significant correlations were found between numbers or length of sculpin collected and the depth, velocity, or substrate type at the point of collection.

7. A provisional estimate of annual production for slimy sculpin in the upper Chena River was 8.5 kg/ha, based on the assumption of 10,000 sculpin/ha.

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